

## **An ecological analysis of the composition and condition of woody plants in urban and suburban ecosystems of the Khopyor River Region**

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**Abstract.** The aim: to perform research of the species composition and condition of urban and suburban ecosystems of the Khopyor River Region. The route method was used for the species composition of woody plants. Also, using this method the conditions of the growth of trees and shrubs were described. The data of field ecological observations and researches were analyzed in the laboratory conditions. Plant species were identified by means of determinants. The geographical analysis and floristic belonging of plants in towns and villages is carried out. A diagnostics of the vital state of woody plants is carried out according to the complex of their external signs on ecologically different territories. The results. It is found that the greatest species diversity is characterized by the family Rosaceae Juss. The poverty of the species composition of woody plants in the towns and villages of the research area is associated with insufficient introduction. The largest number of species of trees and shrubs in urban areas are characterized by parks and squares. Of great concern is the weakening of the vital condition of woody plants in the area of suburban highways. The greatest values of damages of the objects of the research are revealed at wood plants as part of roadside territories of towns and villages. The expediency to restore greening in ecologically problematic urban areas is obvious.

### **1. The introduction**

Green spaces are the most important component of the ecological infrastructure of modern towns and cities. They are the most active tool for the reconstruction of their architectural and planning structure [1; 2]. Woody plants together are the main biological elements in the formation of a comfortable urban environment [3; 4]. These organisms have signs of ecological optimization of the anthropogenic environment. In artificial and natural ecosystems they perform the role of engineers formed by phytocenoses [5; 6; 7; 8, 9].

To understand the ecological functionality of woody plantations, it is necessary to have a clear understanding of their composition. The composition of woody plantations together with the economic and operational orientation of urban complexes determine their ecological and hygienic condition. Also, the composition of woody plantations determines the resource, aesthetic and ecological importance of urban and suburban ecosystems [10; 11]. After all, woody plants in the green spaces of urban landscapes are the basis of terrestrial ecological frameworks.

The condition and functionality of woody plants strongly depend on the parameters of the environment in the growing areas [12; 13, 14]. Accordingly, the parameters of ecology-hygienic and psycho-emotional comfort of the urban environment depend on the composition and ecological state of green plants. The species composition of woody plantations is largely formed by the peculiarities of people's perception of the visual space of populated places. Insufficient saturation of settlements with resources of woody plants causes negative psychophysiological reactions of the human body [15; 16; 17; 18].

The purpose of bioecological research (2010-2019) was to determine the species composition of woody plants in urban and suburban ecosystems, to carry out its ecological analysis. The objects of the

research were representatives of cultural dendroflora in the urban ecosystems of the Khopyor River Region.

The Khopyor River Region is in Central Russia. It is formed by the valley of the Khopyor river. It is very winding and defines a variety of valley complexes. The basin of this river covers four regions: Penza, Saratov, Voronezh and Volgograd regions. The territory of the Saratov region is the middle part of the Khopyor River Region. The research area covered the Western part of the Saratov region. It is located in the Oka-Don lowland plain.

Among the soil-forming rocks, clay and heavy loam dominate the territory of the research area. Sandstones are common. The relief has a relatively leveled character. It is also characterized by slight gradation, ribbing. Erosion processes are widespread. Azonal forests (floodplain forests) have developed in the valley of the Khoper river and its tributaries [19].

On the territory of the Oka-Don lowland plain, lowland-steppe and lowland-forest-steppe landscape provinces are distinguished. The area is dominated by various chernozems [20; 21]. They determine the soil and ecosystem diversity of the area. They form mainly steppe and forest-steppe ecosystems.

Most of the chernozem soils are plowed. The processes of soil degradation of agricultural landscapes due to erosion and technogenic and chemical pollution are obvious [22; 23].

Critical environmental situations in the Khopyor River Region are more typical of urban complexes. Urban and suburban construction, various economic activities and complex nature management contributed to the formation of technogenically transformed soils (different variants of urban soils). They were used for the realization of most of the objects of engineering, architectural and green construction. In the area of the research there is a widespread mechanical transformation of soils and geological basis, technogenic pollution of soils, air and plant organisms [24; 25]. These anthropogenic causes conditioned the artificial nature of the formation and dynamic development of ecosystems in the settlements of the Khopyor River Region. Artificial phytocenoses in the research area are represented by different types of green plantations. Natural ecosystems in most of the areas have been significantly transformed.

## **2. The methods of the research**

By means of the route method, we kept a record of the composition of woody plants in urban and suburban ecosystems of the Khopyor River Region. Linear and areal types of woody plantations in different categories of territories were examined. In addition, the conditions of growing places of trees and shrubs were recorded. The collected data of the route accounts were analyzed in the laboratory conditions. By means of determinants the identification of the considered species was carried out [25; 26]. The analysis of the representation of species and genera formed by them are presented in graphical form (in the form of histograms in Figures 1, 2). Arithmetic mean values of the species representation of the introduced trees and shrubs in urban ecosystems of the research area are also presented in the form of a histogram (Figure 3).

The geographical analysis of the considered species of woody plants was carried out. Their floristic identity in towns and villages of the Khopyor River Region was defined. On the basis of the obtained data and their analysis, it is concluded that it is expedient to introduce new species of trees and shrubs into the culture.

The vitality of woody plants was determined by the complex of signs of their sanitary condition [28; 29]. The results of ecological diagnostics of woody plants were averaged and statistically processed. The data of the research were realized in a 95% confidence interval.

## **3. The results of the research**

In the research area, the climate is moderately continental. Processes of aridization are manifested. Summer is dry and hot. The climate of the research area generally corresponds to the climatic features of the south-east of Russia. Its arid nature significantly limits the vegetation of plants (on average from mid-May to mid-September in the research area). To a significant extent, it also determines the poverty of species composition of woody plants in natural and cultural ecosystems.

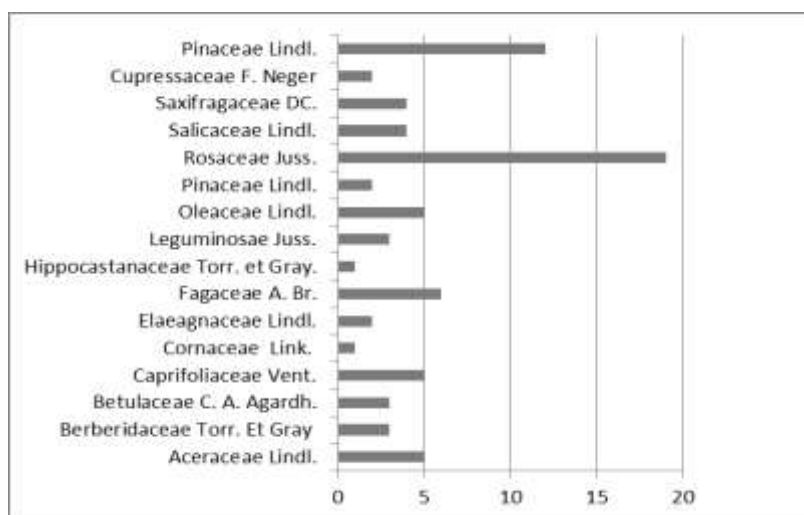
Forest phytocenoses have developed in natural floodplain geocomplexes. The main forest-forming breed in them is *Quercus robur* L. Its populations up to 70% are formed by individuals of vegetative origin. In floodplain ecosystems the common plants are *Populus tremula* L., *P. alba* L., *Acer platanoides* L., *Betula pendula* Roth., *Malus sylvestris* (L.) Mill., *Tilia cordata* Mill., *Alnus glutinosa* (L.) Gaertn., *Sorbus aucuparia* L., *Ulmus laevis* Pall. and other species. Mainly wooded areas are occupied by the individuals *Q. robur* L., *A. negundo* L., *Fraxinus pennsylvanica* Marsh., representatives of the genera *Ulmus* L., *Malus* Mill., *Elaeagnus* L., *Salix* L. and others. This is consistent with previously published scientific materials [30].

The natural ecosystems of coniferous forests are small in area. To a greater extent, linear and areal plantings of coniferous plantations near towns, villages, along highways are common. The phytocenoses of coniferous forests are formed by *Pinus sylvestris* L. of different age and life condition.

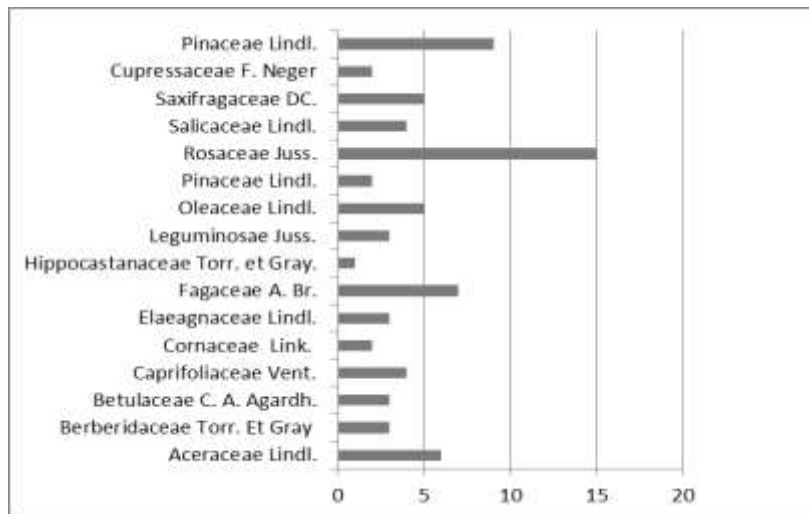
In suburban areas forest ecosystems are functionally designed to provide mainly ecological, conservation and recreational functions. Within urban complexes phytocenoses solve landscape-planning, sanitary and hygienic, ecology improving, recreational, social and aesthetic problems. Their aggregate autotrophic component is represented by green plantations. In the environment-forming and ecologo-optimizing plan (for people), planting trees and shrubs is of great importance. They form the basis of linear and areal plantings. Wood plantings are the basis of the environmental frameworks of towns and villages of the Khopyor River Region.

Using the example of the urbanized areas of the Khopyor River Region, a complex of research on accounting, identification and ecological analysis of the composition of wood plantings was implemented. Great importance was attached to the analysis of the systematic structure, geographical origin and floristic belonging of woody plants.

Figures 1, 2 show the distribution of families by the largest number of plant species (using the example of the village of Pady and the urban-type settlement of Romanovka).



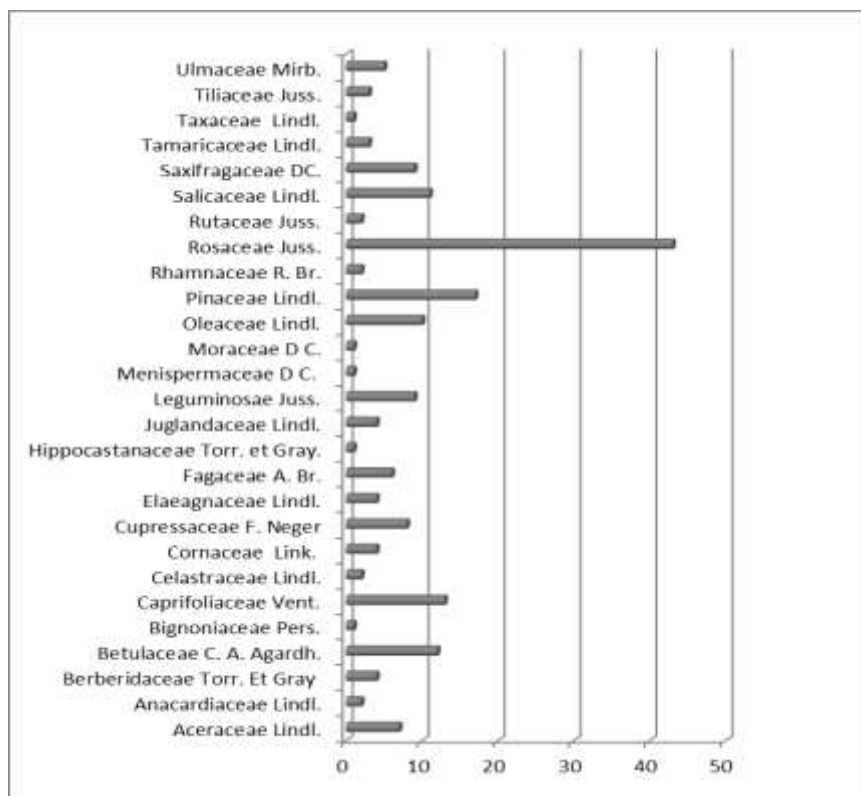
**Figure 1.** The number of genera in the families of plants used in the greening of the village of Pady (Balashov district)



**Figure 2.** The number of genera in the families of plants used in the greening of the work settlement of Romanovka

In the first case (Figure 1) the Rosaceae Juss family, Pinaceae Lindl. and Fagaceae A. Br. reach the largest number of species. In the second case (Figure 2) the situation is similar. The diversity of Aceraceae Lindl species increases slightly in the structure of urban ecosystems.

It is interesting to analyze the distribution of the number of species of woody plants in the families they form. The average arithmetic values for the towns and villages of the Khopyor River Region (Samoylovka, Balashov, Romanovka and Arkadak districts) are presented in Figure 3.



**Figure 3.** The number of genera in the families of plants used in the greening of the urban landscapes of the Khopyor River Region

Figure 3 shows the following. In the plantations of the research area the largest number of species is represented by the Rosaceae Juss family by (50 species), Pinaceae Lindl. (17), Betulaceae C. A. Agardh (16), Caprifoliaceae Vent. (14), Salicaceae Lindl. (13 species). Of the family Rosaceae Juss. the most common are *Sorbus aucuparia* L., *Crataegus sanguinea* Pall., *M. baccata* (L.) Borkh., *Prunus tomentosa* Thunb., *P. spinosa* L., *Rosa canina* L. and a number of other species. Of the family Pinaceae Lindl. in plantings are used: *Picea abies* (L.) Karst., *P. pungens* Engelm., *P. silvestris* L., *Pseudotsuga menziesii* (Mirb.) Franco and others. From other families in the research area grow: *B. pendula* Roth., *B. pubescens* Ehrh., *Sambucus nigra* L., *P. alba* L., *P. nigra* L., *Corylus avellana* L., *Viburnum opulus* L., *S. fragilis* L., *S. alba* L., *Lonicera xylosteum* L. Other families in the woody plantations of the urbanized areas of the Khopyor River Region are represented by ten or fewer species.

Of particular ecological, social and recreational importance are the cultural phytocenoses within the recreation areas of the settlements of the Khopyor River Region. Among such objects it is necessary to note the park named after Kuibyshev and park "Teatral'ny" in the town of Balashov. That is a particular example of the introduction of ornamental deciduous and coniferous shrubs and trees on the limited territory of the centre of this settlement (the reconstructed park "Teatral'ny"). Great ecological, tourist, regional, therapeutic, recreational, historical, and cultural significance belongs to the old manor of the nobility "Razdolye" in the village of Pady (Balashov municipal district). The gardens, squares and parks of the urban and rural areas of the Khopyor River Region have a unique layout. They are organically integrated into urban and rural landscapes. These greening compositions include transport (linear) and nodal objects of ecological frameworks. In general, the green areas within recreational zones represent the structural and functional cores of the ecological infrastructure of modern towns and villages of the research area.

In the gardens, parks and squares of the research area biological groups and single specimen are represented by *Acer* L., *Fraxinus* L., *Tilia* L., *Sorbus* L., *Salix* L., *Ulmus* L., *Betula* L., *Syringa* L., *Prunus* L., *Picea* Dietr., *Pseudotsuga menziesii* (Mirb.) Franco, *Aesculus hippocastanum* L., *Thuja occidentalis* L., *Caragana arborescens* Lam. Highly decorative shrubs are characterized as part of biological groups. These are representatives of *Berberis* L., *Amelanchier* Medic., *Rosa* L., *Spiraea* L., *Euonymus* L., *Lonicera* L., *Syringa* L., *Sambucus* L., *Physocarpus* Maxim. That is a favourable tendency in the greening of gardens and parks of the urbanized areas of the Khopyor River Region from the aesthetic, landscape-optimizing, sanitary and hygienic, and environmental points of view.

In linear plantings a few representatives of the trees – *Populus* L., *Ulmus* L., *Tilia* L., *Acer* L., various species of shrubs are used. In the form of single specimen *P. italica* (Du Roi) Moench, *S. alba* L., *Catalpa bignonioides* Walt are used. It is obvious that the introduction of woody plants in the garden and park areas of towns and villages of the research area has not been sufficiently investigated.

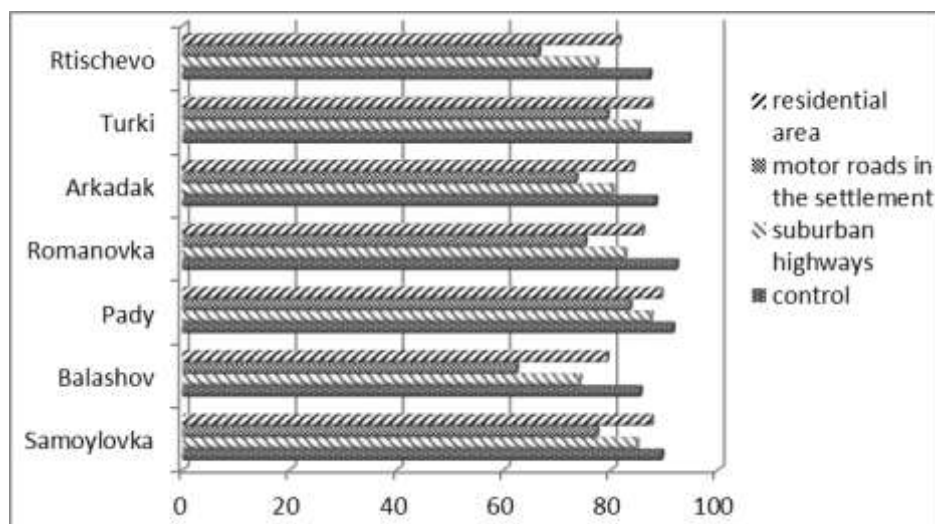
Of the coniferous introducers *P. menziesii* (Mirb.) Franco, *P. canadensis* Britt., *P. pungens* Engelm., *P. abies* (L.) Karst are scantily used in the parks. Overall, in urban and rural areas of the Khopyor River Region they are slightly spread. They mainly grow in groups and singly in parks and in some squares. *P. silvestris* L. and species of the genus of the *Picea* A. Dietr singly grow in the public, business and residential areas.

The registered coniferous plants are quite adapted to the urban environment and to the conditions of a temperate climate. Therefore, in the area of the research they must be introduced into culture everywhere because of their ecological and resource and high aesthetic qualities. In addition, they are of high importance as year-round indicators of the state of the environment [31]. From representatives of the genus Rosaceae Juss. (*Cotoneaster lucidus* Schlecht. and other species) the hedges of parks and gardens) are organized. That is a positive moment in nature management from ecological and landscape planning positions. Plants of this family provide wide opportunities for various purposes of urban and rural gardening.

The analysis of the results of the research of the species composition showed the following. In the composition of ecosystems in the towns and villages of the Khopyor River Region grow 200 species of trees and shrubs. They comprise 77 genera and belong to 28 families. The observations of the territory of Balashov and other settlements revealed a significant transformation of dendroflora. This significant circumstance reduces the species diversity of plantations and their quality. This is typical of all urban ecosystems of the Khopyor River Region.

The most significant geographical sources for the introduction of woody plants are Europe (36.4% of the total number of species), Siberia and the Far East (20.1), North America (14.2), Middle, Central and Western Asia (13.6%). Woody plants from Korea, China, Japan (10.5%), Asia Minor (5.2%) were used in greening to a minimum extent.

The arithmetic mean data of the ecological diagnostics of woody plants are given in graphic form in Figure 4. In comparison, the statistically processed results of determining the index of life status of these organisms in different territories are presented.



**Figure 4.** The index values of the life status of woody plants in the ecologically diverse areas of the Khopyor River Region, %

Woody plants in suburban forests (control values) are characterized by a relatively healthy state of life. This applies to deciduous and coniferous plants. The best situation in this case is characteristic of the suburbs of the village of Pady, the work settlements of Romanovka and Turki.

In suburban areas along the highways a weak level of damage to woody plants was found only for Balashov and Rtischevo. These towns are characterized by the greatest aggregate exploitation and technogenic pressure on artificial and natural ecosystems. Woody plants in their composition experience a depressing effect. In the area of other settlements the condition of woody plants is much better. They are relatively healthy as part of roadside plantations and in areas of preserved natural forests.

In the area of motor roads of the settlements the ecological situation is relatively tense. Woody plants are in relatively healthy life condition only in Pady. In other urban systems a weak level of damage to this group of organisms was revealed.

Significantly better environmental condition is identified for woody plants in the residential zones in the urbanized areas of the Khopyor River Region. Only in Balashov they are characterized by minor damage. In residential areas the total technogenic pressure is lower if compared to other categories of urbanized areas.

Thus, the results of the research in the Khopyor River Region showed the obvious poverty of the species composition of woody plantations in towns and villages. The resources of introduction of woody plants into the urban complexes of this territory are used fragmentally and very little.

A low species diversity of woody plants supports their vulnerability to negative anthropogenic factors. Economic and technogenic activity of urbanized territories contributes to the weakening of the ecological condition and stability of woody plants in the artificial and natural ecosystems of the Khopyor River Region. The increasing activity of the transport component in the urban economy increases the technogenic pressure on woody plants. The decrease in their life status was diagnosed in other functional zones of towns and villages of the research area.

The route surveys of urbanized areas revealed a lack of compensatory greening. There is definitely a need for updating the plantations of woody plants. Activities for the care of woody plantations are clearly episodic (primarily in urban parks). There is an urgent question about the need for special measures to protect green plantations of general and limited use. Taking into account the above circumstances, this mainly applies to transport and residential areas, public and restricted areas. To a significant extent this situation is aggravated by insufficient financing of greening and environmental protection works, a lack of rain in summer, aridity of the local climate.

#### **4. The conclusion**

The relative poverty of the species composition of shrubs and especially trees was found. Registering, studying and analyzing the composition of woody plantations in urban ecosystems of the Khopyor River Region revealed the quantitative predominance of the following families: Rosaceae Juss. (50 species), Pinaceae Lindl. (17), Betulaceae C. A. Agardh (16), Caprifoliaceae Vent. (14), Salicaceae Lindl. (13 species). Other families are represented to a small extent by species of trees and shrubs in the research area. The process of synanthropization of urbanized flora contributed to the quantitative dominance of the representatives of Rosaceae Juss. and a number of other families. Deciduous trees and shrubs (through greening and accidental drift) have reached the greatest distribution in urbanized areas. At the same time, conifers are used in greening to a limited extent. Basically, they grow only in park areas (in the form of single specimen and groups). In other territories their single specimen are revealed.

The results of registering and analyzing the composition of woody plantations revealed promising floristic sources for expanding the greening range. The most promising geographical sources for greening of villages and towns of the Khopyor River Region are the East Asian, Circumboreal, Iran-Turanian and North American Atlantic floristic regions of the globe.

The deterioration of the ecological condition within the urbanized areas of the Khopyor River Region initiated the weakening of the life status and the decrease in the stability of trees and shrubs. Bedding of these plants along country highways and roads in settlements are quite vulnerable to technogenic pressure. In this case vitality is a complex indicator of the sanitary and ecological state and biological stability of woody plants. Woody plants in the research area determine the shape, structural organization, productivity and functionality of urban ecosystems. Therefore, in fact, the functionality and stability of the terrestrial ecological frameworks of the region under consideration is severely limited. In essence, this represents a cumulative additional condition of the crisis ecological state of the urbanized territories of the Khopyor River Region. Also, a relevant environmental and urban planning problem is the overall reduction of green plantations in towns and villages. At the same time, adventitious woody plants displace representatives of dendroflora in the composition of urban artificial and natural phytocenoses. The identified problems are characteristic primarily of the private sector, residential areas of small and medium height, transport, industrial and communal storage zones.

Complex works on purposeful introduction are practically not carried out. They are very episodic, limited in nature. These reasons do not contribute to the effective solution of the problems of renewal, reconstruction and creation of new woody plantations in the towns and villages of the Khopyor River Region. Against the background of aggravation of crisis ecological situations, the solution of the issues of introduction of trees and shrubs is an actual scientific and practical task of an environmental-protective and environmental-stabilizing plan.

The introduction of these plants is especially necessary for the creation of sustainable and effective ecological frameworks in the settlements of the area under study. It is useful to create dendrological nurseries in the largest urbanized areas of the Khopyor River Region (Samoylovka, Balashov, Romanovka, Arkadak, Turki, Rtischevo) (for example, at greening educational organizations). They can solve fundamental (bioecological) and actual practical problems (selection and preparation of suitable materials for greening). It is important to select species and varieties of trees and shrubs in accordance with local natural geographical, landscape planning and environmental conditions. In suburban areas, reforestation and measures to protect the main forest belts are required. At present it is necessary to enrich the species composition of green spaces with new species with useful ecological and decorative qualities. This will solve the problems of environmental management and environmental protection. Upgrading existing plantings will improve their ecological status and ensure the sustainability of urban and suburban ecosystems.

At present and in the near future it is expedient to develop various garden and park greening of towns and villages of the Khopyor River Region. After all, recreational areas are characterized by a special social need for recreation, rehabilitation and emotional and aesthetic satisfaction of residents. It is important that they are multifunctional and provide recreational resources to all cohorts of the population. One of the leading values is the compliance of greening with environmental requirements and principles of rational urban environmental management. Only in this way will they contribute to environmental security and sustainable development of settlements. This applies to the entire Khopyor River Region: within the Saratov, Penza, Voronezh and Volgograd regions.

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